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Influence Of Measurement Frequency On Rating Of Perceived Exertion During Sub-Maximal Treadmill Testing

Sue Stout
Eastern Illinois University

This research is a product of the graduate program in Kinesiology and Sports Studies at Eastern Illinois University. Find out more about the program.

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INFLUENCE OF MEASUREMENT FREQUENCY ON

RATING OF PERCEIVED EXERTION

DURING SUB-MAXIMAL TREADMILL TESTING

BY

SUE STOUT

THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

MASTER OF SCIENCE IN KINESIOLOGY AND SPORTS STUDIES

IN THE GRADUATE SCHOOL, EASTERN ILLINOIS UNIVERSITY
CHARLESTON, ILLINOIS

2010

I HEREBY RECOMMEND THAT THIS THESIS BE ACCEPTED AS FULFILLING THIS PART OF
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ABSTRACT

Previous studies have suggested that ratings of perceived exertion (RPE) may be influenced by the frequency of measurement interval during both sub-maximal and maximal exercise testing. The purpose of this study was to further examine the effect of inquiry frequency on perceived exertion during sub-maximal treadmill testing. Twelve recreationally trained female college students completed one of two graded treadmill tests with a crossover design for the other protocol on a nonconsecutive day. During one trial, RPE and heart rate (HR) were recorded at the end of each three-minute stage. During the other trial, RPE and HR were monitored three times per stage, at the end of each minute. A two-way MANOVA, with repeated measures for both test condition and test stage, was used to determine if there were significant differences in HRs or RPEs at each stage with more frequent inquiries. No significant differences were observed in HR ($F=0.163$, $df=1$, $p=.694$). Although not statistically significant in this study, RPEs were somewhat higher at each stage ($F=2.384$, $df=1$, $p=.151$). Further examination of test order revealed lower RPEs were given during the second test, regardless of the frequency of measurement interval. Analysis determined these differences approached statistical significance ($F=3.945$, $df=1$, $p=.072$), suggesting order effect may have contributed to higher RPEs. It is possible the participants reported higher RPE levels during the first test as a result of their anxiety. Increased familiarization with the test protocol may have contributed to the lower perceived exertion during the second test. From the results of this study it was concluded that increased frequency of measurement interval did not significantly influence RPE during sub-maximal treadmill testing in this study of college females.

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I owe my deepest gratitude to our children, grandchildren and especially my husband, Jerry, for allowing me to spend so much time in pursuit of my undergraduate and graduate degrees at Eastern Illinois University during the past four years. Your kindness and patience will always be remembered.

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CHAPTER I

INTRODUCTION

The Borg 15-point rating of perceived exertion (RPE) scale is widely accepted as a valued and reliable instrument for evaluating perceptual intensity of whole body exertion during exercise (Corbett, Vance, Lomax & Barwood, 2009; Hampson, Gibson, Lambert & Noakes, 2001). Swedish psychologist Gunnar Borg developed this scale in the late 1950s and the 1960s, when he determined it was necessary to have a defined method that could facilitate comparison of perceptual responses given by different people, at different locations and in different situations. His research revealed exercise intensity can be interpreted in different ways (Borg, 1998). Borg found exercise intensity to be defined by physical measurements such as power, work, energy, torque, velocity, etc. In addition, he determined it to be interpreted physiologically, in absolute terms such as VO2 or by a relative value, such as heart rate (HR). He also determined exercise intensity may be evaluated in terms of ratings of subjective intensity as perceived by the subject, giving an individualized meaning of exercise intensity. Of the many factors related to exercise intensity, Borg (1998) believed HR to be a common measure of degree of exertion, and that an individual's own perceived exertion provided the single best indicator of actual physical exertion and intensity of exercise (Borg, 1982). His subsequent 15-point scale, with values ranging from 6 to 20, provided a perceptual measure with a linear relationship to HR during exercise (Noble & Robertson, 1996). Borg believed a direct correlation existed between a perceived exertion rating times ten and the actual HR during physical activity (Adams, Schafer, Tipton & Johnson, 2008;

Borg, 1998; Borg, 1982). Therefore, the values from 6 to 20 could be compared to heart rates ranging from 60-200 beats per minute. Borg cautioned this close relationship was not intended to be taken too literally, as the meaning of a certain HR value as an indicator of strain depends upon a variety of factors, such as age, type of exercise, environment and anxiety (Borg, 1982). While Borg's RPE scale was initially believed to provide a direct correlation between perceived exertion and HR, a subsequent meta-analysis concluded that the evidence supporting HR as an indicator of perceived exertion was not consistent. Heart rate did not show a stronger relationship with RPEs than other physiological measures such as blood lactate concentrations, oxygen uptake and ventilation rate (Chen, Fan & Moe, 2002).

RPE responses, used to determine the degree of fatigue reached, may be compared between exercise tests. Protocols for various common graded exercise tests vary from inquires made only once per test stage to once each minute during the assessment. The length of each test stage may vary from as little as 30 seconds in some protocols to three minutes or more in other treadmill protocols. Individualized protocols offer even more variation for use of the RPE responses. Psychological factors may influence ratings of perceived exertion in other exercise tests. Borg believed exertion and fatigue are states with both physiological and psychological aspects. He concluded an individual's mental reactions, fear, anxiety, motivation, emotions and personality during exercise may influence perception and performance (Borg, 1998). While Borg believed it is impossible to study fatigue and exertion from only a physiological perspective, he accepted exercise intensity could also be interpreted in absolute physiological terms, such as VO2 and HR

(Borg, 1998). Other physiological responses, such as blood lactate and ventilation, may similarly be used as a reflection of exertion.

Timing may also influence perceived exertion. Reliability of the Borg RPE scale comes into question with differing frequencies of inquiry during both maximal and sub-maximal graded exercise testing. Corbett et al. (2009) studied the influence of frequency of measurement interval on RPE during sub-maximal treadmill testing of males during a 35-minute constant speed test. Han, Whaley and Kaminsky (2001) examined males and females during three stages of a maximal graded exercise test. Both studies found increased frequency of inquiry led to higher RPEs at a given intensity. This supports the assumption that perception of exertion can be altered by attentional focus during exercise, and more frequent assessment may lead to a higher RPE at a given intensity. With varying degrees of intensity used from stage to stage in common treadmill test protocols, a more standardized RPE inquiry procedure could provide better use of the Borg scale when used to compare the degree of fatigue reached from one test to another. Further research utilizing a protocol with gradually increasing workloads could provide more comparative stages in less overall test time. Similar results following assessment of only female participants could also support the assumption that more frequent measurement influences perceived exertion. Similar findings in subsequent studies that utilized different protocols and participants would serve to strengthen the validity of the test conclusions.

Purpose

The purpose of this study was to examine the effect of frequency of measurement interval on rating of perceived exertion and heart rate during sub-maximal graded treadmill testing.

Hypothesis

It was hypothesized that the frequency of RPE measurement interval would influence ratings of perceived exertion during sub-maximal treadmill testing, with no differences in heart rates observed during the same stages of testing.

Limitations

Possible limitations of this study included the limited age range and relatively small number of participants.

Definition of Terms

Dyspnea: subjective sensation of shortness of breath, breathlessness or inadequate breathing

Ramp protocol: exercise test that provides continuous or frequent increases in speed and grade

Rating of perceived exertion: an individual's subjective assessment of how hard he or she is exercising

Self-efficacy: the belief that one is capable of performing in a certain manner to attain specified goals.

Sub-maximal graded exercise test: fitness assessment performed at progressively increasing workloads below maximal exercise intensity

Teleoanticipatory: pertaining to the subconscious, fatigue-avoidance mechanism that takes into consideration a finishing point, a pacing strategy

CHAPTER II

REVIEW OF LITERATURE

Validity and reliability are critical to the accepted scientific use of any measurement tool, including perceived exertion (Noble & Robertson, 1996). The factors mediating the perception of effort or exertion during exercise are numerous and not clearly understood. Furthermore, the literature has not identified a single variable that consistently explains RPE (Hampson et al, 2001). Borg (1985) believed it was necessary to measure as many moderating variables as possible in order to fully understand and accurately assess the nature of an exercise behavior. This review of literature examines the influence of test protocol, psychological factors, physiological factors and RPE measurement interval on rating of perceived exertion.

Test Protocol

Glass, Whaley and Wegner (1991) determined the RPE value given at target HR during graded exercise testing varied as a function of the test protocol, test duration and gender differences. Their study examined a total of 30 young, healthy university students. None of the 15 males or 15 females reported any participation in vigorous aerobic exercise training within the previous three months. Standard Bruce protocol, with three-minute stages, and a modified Balke, with two-minute stages, were used. The modified Balke protocol elicited a greater RPE at target HR than the Bruce protocol in both males and females. The greater RPE may have been due to: (1) the local discomfort associated with the excessive incline obtained in the modified Balke, (2) the extended time necessary to complete the test, and/or (3) the more frequent measurement of RPE in the shorter stage duration.

A study of six young male university track or cross-country students compared their perceived HRs with values observed on pulse monitors. The investigation revealed HR perception improved during thirteen weeks of treadmill running at a HR of 140 beats per minute, which compared favorably with the accuracy of either pulse counting or rating of perceived exertion. Researchers chose an individualized protocol for this study, using three-minute stages to assess HRs and RPEs (Yamaji, Yokota & Shephard, 1992).

Skinner, Hutsler, Bergsteinova and Buskirk (1973) examined eight lean and eight obese young male university students to determine whether they could perceive small intensity differences when the workloads were presented in a random order. All subjects were given two trials on two bicycle ergometer protocols. One test progressively increased the workloads to a self-imposed maximum, whereas the other randomly assigned work loads. During the progressive test, the exercising began at 150 kgm/min and the intensity subsequently increased by 150 kgm/min every two minutes until exhaustion. During the random test, subjects pedaled two minutes at 150 kgm/min, at which time the workload increased to either 300, 450, 600, 750 or 900 kgm/min. The random intensity was maintained for four minutes in order to allow the subject to reach steady state. Following an 8-minute rest period, another random workload was selected and the subjects followed the same procedure until all five workloads were completed. Heart rate, respiratory frequency and RPE were recorded twenty seconds prior to the completion of each workload in both the progressive and random order tests. The study concluded the subjects were able to perceive small differences in intensity and no significant differences were found in the physiological or perceptual variables between the progressive and random order tests.

Doherty, Smith, Hughes and Collins (2001) assessed RPE every 30 seconds during the first two minutes in an individualized protocol using short-term, constant-load, high-intensity exercise (ST). Fifteen sprinters, middle-distance runners or multiple-sport athletes performed the treadmill test for 3-4 minutes to a volitional exhaustion at an intensity equivalent to 125% VO2 max. RPE was not collected during the latter part of their study due to excessive and disorienting fatigue associated with high intensity exercise. Their investigation revealed RPE during ST displayed a positive linear response during the first two minutes and could be used as a reliable new dimension to ST investigation. It was concluded more studies were needed to investigate the perceptual response to ST.

A study of nineteen female college students (ages 19-22 years), determined RPE to be useful as a rough estimate of perceived exertion, but not accurate enough to be used as a substitute for a measured HR (Adams et al. 2008). When RPE was used to predict HR, the predicted HR averaged 22-24 bpm lower than the actual HR. Participants in this study performed a modified Bruce sub-maximal treadmill-walking test.

Mahon, Plank and Hipp (2003) examined 15 ten year-old children to determine whether differences in the power output increment during a graded exercise test affected the overall RPE at sub-maximal and peak exercise intensities in boys and girls. Power output increased by 10 watts per minute in one test protocol and by 30 watts every three minutes in the other protocol following a 2-minute warm-up at 20 watts. Sub-maximal and peak cardiorespiratory and perceptual responses were measured each minute. The cardiorespiratory and RPE responses recorded at the fifth minute (50 W), eighth minute (80 W), at ventilatory threshold and at peak exercise were compared. Ratings of perceived exertion were recorded at the end of the 2-minute warm-up stage and every minute thereafter. While the results of the study indicated there were differences in cardiorespiratory responses at 50 W and 80 W, there were no differences in RPE. It was also noted cardiorespiratory responses at ventilatory threshold were similar, despite differences in RPE. The authors concluded the perception of effort at a given sub-maximal power output in boys and girls is not affected by the manner in which the power output is incremented, as long as the overall rate of increase is constant.

The selection of test protocol varied greatly in the above studies of perceived exertion. Yamaji et al. (1992) chose an individualized protocol and determined that perception of HR could be improved with training. Glass et al. (1991) utilized a modified Balke and Bruce protocols and found that the RPE values at a given HR varied as a result of the test protocol, test duration and gender of the subjects. Skinner et al. (1973) chose an individualized maximal protocol and found that the subjects were able to perceive small differences in intensities. Doherty et al. (2001) also chose an individualized, short-term maximal protocol with constant load and high intensity. Adams et al. (2008) found that RPE was useful as a rough estimate of perceived exertion, but not accurate enough to be substituted for HR in their sub-maximal, modified Bruce protocol. Mahon et al. (2003) also chose a sub-maximal graded protocol to test the perception of effort of young boys and girls.

Psychological Factors

Psychological factors have also been used to explain variance in perceived exertion. A study of 103 girls, ages 8-17, was conducted to determine if self-efficacy influenced ratings of perceived exertion during a 20-minute cycle ergometer test. Participants rated their level of confidence in being able to successfully complete each of eight cycling tasks that increased in 5-minute increments from 5 to 40 minutes, cycling at a fast pace without stopping. Each participant pedaled at 60% of her peak VO2. The study concluded higher levels of self-efficacy decreased ratings of perceived exertion during the cycling test (Pender, Bar-Or, Wilk and Mitchell, 2002).

Williams and Eston (1986) studied 30 young, physically active males (mean age 16 ± 1.0 years) to examine the relationship between extraversion, exercise intensity and perception of exertion. All subjects completed the Junior Eysenck Personality Inventory, which was designed to measure two major personality dimensions, extraversion and neuroticism. All subjects also completed a sub-maximal cycle ergometer test to predict maximal oxygen uptake and maximal power output. During their first test, the subjects cycled for 5 minutes at an intensity of 50 watts at 60 rpm until they reached steady state. Intensity was increased to a prescribed level according to heart rate response and then maintained for 3 to 4 minutes until steady state was reached in level 2. This procedure was repeated at a third level. A line representing the relationship between power output and HR was drawn between the steady state HR at levels 2 and 3 and then interpolated to an age-predicted maximal HR. Maximal oxygen consumption and maximal power output were also predicted for each subject during this first test. In a second test, each subject cycled for 3 to 4 minutes during each level at intensities of randomized order representing

30%, 60% and 90% of his predicted maximal power output. During the final 15 seconds at each exercise level, the subjects reported their Borg rating of perceived exertion. Results of the Junior Eysenck Personality Inventory indicated the subjects in this study were significantly more extraverted than the general population ($p < 0.05$). The study also confirmed the young males were able to accurately perceive the physiological costs of their exercise, regardless of the introversion/extroversion dimensions of their personalities. The extroverts were not more tolerant of pain than the introverts. The authors noted this was contrary to the findings of Petrie (1967) who contended personality differences influenced perception of effort, with extroverts having a greater tolerance for pain than introverts. The authors cautioned the extraverted bias of this sample group might have depressed the correlation values.

Dishman, Graham, Holly and Tieman (1991) questioned previous studies that determined exercise tolerance is overestimated in individuals exhibiting Type A Behavior Pattern (TABP) because of high motivation and suppressed ratings of perceived exertion. Their study of 86 middle-aged Caucasian men, who were entry-level participants in an adult fitness program, used the Jenkins Activity Survey, the Bortner Rating Scale and the Framingham Type A questionnaire to assess TABP. Their treadmill test protocol began with a 5-minute walk at an increasing grade. The grade was then returned to 0% and each subject was allowed to select a speed at which he could comfortably walk or jog for a 20 to 30 minute exercise session. This speed was maintained while the grade continuously increased by 2.25% per minute until the subjects reached voluntary exhaustion. Heart rate and oxygen consumption were measured throughout the treadmill test and RPEs were obtained during the last 15 seconds of each minute and at peak VO2.

Multiple linear regression analysis found no relations ($p > 0.10$) between estimates of TABP and the physiological responses of the 86 Caucasian males in this study. The authors concluded TABP does not offer useful information for prediction of RPE, preferred exertion level or peak VO2 during graded treadmill testing in this population.

Another study examined the relationship between psychological variables and perceived exertion. Sixteen male and 16 female subjects cycled at 600 kpm for 2 minutes, followed by one-minute intervals at 200, 400, 800 and 1,000 kpm in a random order. Rating of perceived exertion was assessed at each workload. While male subjects demonstrated a significantly lower mean HR at each workload, the mean perceived exertion for the males and the females did not differ significantly. Multiple regression analysis between perceived exertion and selected psychological variables (depression, extraversion, tension and neuroticism) resulted in a multiple R of .67 for the males. When depression, neuroticism and extraversion were combined for the females, a multiple R of .48 was obtained. The study concluded that psychological variables brought about different influence on perceived exertion for the males and the females. While psychological variables contributed the most influence on perceived exertion for males, female perceived exertion was most altered by HR (Milhevic, 1978).

Baden, McLean, Tucker, Noakes and Gibson (2005) tested sixteen male and female runners who completed three sessions of treadmill running at a constant 75% of their maximal treadmill running speed. In their first trial (20 MIN), each runner was instructed to run for 20 minutes and each was stopped at 20 minutes. In the second trial (10 MIN), runners were instructed to run for 10 minutes, but at 10 minutes, each runner was instructed to run for an additional 10 minutes. In the final trial, (unknown) runners were not instructed how long they would be running, but were stopped at 20 minutes. The study determined that rating of perceived exertion increased significantly between 10 and 11 minutes in the 10 MIN trial compared with the 20 MIN and unknown trials ($p<0.05$), even in the absence of increased heart rates. It was concluded that rating of perceived exertion has an affective component and is not purely a measure of physical exertion.

In a similar study, fifteen moderately fit males completed two separate treadmill runs at a pace representing 85% of their maximal oxygen uptake to examine the effects of anticipated task duration on ratings of perceived exertion. In one test, the subjects ran for 20 minutes. During the other treadmill test, the subjects were led to believe they would be running for 30 minutes, but the test was also terminated at 20 minutes. A lab timer remained in full view throughout each trial to ensure the subjects were aware of the time remaining during each run. Ratings of perceived exertion, heart rates, respiratory rates and ventilatory minute volumes were collected during each counterbalanced trial. Physiological and perceptual responses were recorded during a 2-minute warm-up, for the first 5 minutes of exercise, at the 10 and 15-minute marks and for each minute thereafter until the test was terminated. While RPEs in the 30-minute trial were lower than RPEs in the 20-minute trial, the authors found it important to note that RPEs for both conditions did not differ significantly from one another during the latter 5 minutes of the tests. Despite the differences in RPEs, the analyses demonstrated no significant differences in heart rates, respiratory rates or ventilatory minute volumes between the two tests. While Baden et al. (2005) found that perceived exertion increased when the task duration unexpectedly increased, the authors of this study determined that perceived exertion was lower when the subjects anticipated continued performance. The study concluded that an expectancy of task duration influenced ratings of perceived exertion during treadmill running, but the effect may be limited to moderate work levels (Rejeski & Ribisl, 1980).

Hampson, Gibson, Lambert, Dugas, Lambert and Noakes (2004) studied overall and localized perceived exertion during sub-maximal, high-intensity running when subjects were deceived. Forty well-trained male and female runners were randomly assigned to one of four groups to complete three 1,680-meter treadmill runs at 80-86% peak speed. The two experimental groups, Expected Similar and Expected Increase, were deceived of their actual run intensities. The two control groups, Control Increase and Control Similar, were informed of the protocol they actually performed. While the three treadmill tests were performed at either 80%, 83% or 86% of the subject's peak treadmill running speed, some runners were told they were running at 83% of their peak, when in reality their intensities varied at 80%, 83% and 86%. Others were told their intensity would vary for each of the three tests, but their intensity remained constant at 83% of their peak treadmill running speed. Ratings of perceived exertion for whole body, chest, legs, head and other areas were solicited following each run. The most significant finding of the study determined all subjects had a similar overall RPE and HR response regardless of whether they were honestly informed or deceived of their actual run intensity. The results of the study also found a low correlation between heart rate and RPE. The authors noted the limited range of intensities, steady-state nature of the exercise and duration of the treadmill runs might have explained the low correlation. They also explained ratings of perceived exertion were only taken at the completion of each run.

In other studies of teleoanticipatory expectations, runners reported their attentional focus and RPE values at regular intervals during both shorter (8-mile or 10-minute) and longer (10-mile or 20-minute) conditions. In the first study, 22 runners participated in a short (8-mile) run and a long (10-mile) run on separate days at the same pace. Attentional focus (proportion of associative to dissociative thoughts) and RPEs were reported at regular intervals. In the second study, 40 runners participated in two treadmill tests at the same speed and gradient. Runners expected to run for 10 minutes (short condition) in one test and for 20 minutes (long condition) in the second test. In both studies, RPE was lower in the longer conditions. It was proposed that the lower RPE in the longer conditions was due to diversion of attention from the physical cues (Baden, Warwick-Evans & Lakomy, 2004).

Stanley, Pargman and Tenenbaum (2007) examined the effects of attentional intervention strategies upon perceived exertion in 13 female exercisers, 18-24 years of age. Their study consisted of five 20-minute sub-maximal cycling tests, involving a 5-minute warm-up, 10-minute physical task and a 5-minute cool-down. The first test determined the HR that would be maintained at 75% VO2 max in the subsequent four tests. An internal association test asked the participants to concentrate on bodily sensations. In an external association test participants were asked to pay close attention to information about their duration of exercise, distance cycled, calories burned, etc. displayed before them on a screen. An internal dissociation cycle test required participants to watch a video of their choice while exercising. During an external dissociation test, bikes were moved to a location that overlooked the entrance to the gym. Participants were asked to monitor the number of males and females who entered and exited the gym during their testing session. Ratings of perceived exertion were monitored at one-minute intervals in all tests. The study found the two associative conditions resulted in higher RPE levels than the two dissociative conditions at the same intensity, suggesting the associative-dissociative dimension influenced RPE.

The above studies have shown that perceived exertion can be influenced by psychological factors. While Baden et al. (2005), Rejeski and Ribisl (1980) and Baden et al. (2004) found that expected task duration affected perceived exertion, Hampson et al. (2004) determined that deception of intensity did not affect perception of exertion. Although Pender et al. (2002) found that higher levels of self-efficacy decreased RPE, Williams and Eston (1986) concluded that personality differences did not influence perception of effort. Dishman et al. (1991) also determined no relationship existed between individuals with Type A Behavior Pattern and their perceived exertion. Milhevic (1978) concluded that psychological variables resulted in different perceived exertion for men and women. Internal association increased RPEs in a study by Stanley et al. (2007).

Physiological Factors

Exercise intensity is reflected in many physiological responses, including oxygen consumption, blood lactate, ventilation and heart rate. A study by Lambrick, Faulkner, Rowlands and Eston (2009) confirmed the strong relationship between the Borg RPE scale and physiological criteria. Their low to moderate intensity cycle ergometer protocol produced accurate estimates of maximal oxygen uptake from sub-maximal HRs and RPEs. Eleven healthy, low-fit women each performed the single graded exercise test utilizing a ramp protocol. Perceptions of exertion were reported every 2 minutes as the participants maintained a constant 60 revolutions per minute as the intensity increased throughout the test. Oxygen uptake and HR were monitored throughout the test as the women exercised to volitional exhaustion. The RPE and HR values, prior to and including an RPE of 13, were extrapolated against corresponding oxygen uptake to theoretical 19 (peak) and 20 (maximal) ratings of perceived exertion, as well as their age-predicted maximal heart rate, to predict maximal oxygen uptake. Results indicated there were no significant differences ($p>0.05$) between measured and predicted maximal oxygen uptake.

Faulkner, Parfitt and Eston (2007) examined 27 men and 18 women to determine if the accuracy of predicting maximal oxygen uptake from sub-maximal HR and RPE values was influenced by gender and habitual activity. Thirteen physically active and 14 sedentary males, and 9 physically active and 9 sedentary females each completed five graded cycle ergometer tests in this study. The initial and final tests were continuous, incremental and determined maximal oxygen uptake. All physically active and sedentary subjects began the tests at 40 W and increased by 40 W every three minutes until volitional exhaustion. Ratings of perceived exertion were obtained during the final 30 seconds of each stage. The three intervening, sub-maximal graded tests were self-regulated by RPE intensities of 9, 11, 13, 15 and 17. The subjects initially cycled at intensities equivalent to an RPE of 9 for three minutes. At the end of each 3-minute stage, intensity was increased to the next perceived effort level and all subjects continued until completing the RPE 17 level. Oxygen uptake, heart rate and RPE were recorded during the final 30 seconds of each stage. Results of this study determined the prediction of VO2 max was not moderated by gender or habitual activity status. The authors also concluded that perceptually-regulated, sub-maximal protocols using RPE range 9-15 or 9-13 can provide valid and reliable estimates of maximal oxygen uptake.

Another study assessed the validity of predicting peak oxygen uptake from sub-maximal RPEs during graded exercise testing in obese women. Forty-three subjects performed a cycle ergometer test, with an initial resistance at 10 W for one minute and subsequent increments of 10 W per minute. The women performed to volitional exhaustion or until they failed to maintain a pedal rate above 60 revolutions per minute. Breath-by-breath respiratory gases were continuously recorded and then averaged during the final 15 seconds of each stage. RPE was collected during the final 15 seconds of each stage until RPE ≥ 15. Individual linear regressions between V02 and RPE ≤ 15 were extrapolated to RPE 20 to predict maximal oxygen uptake, with results indicating the actual and predicted maximal oxygen uptake were not significantly different. The authors concluded accurate maximal oxygen uptake could be predicted during a sub-maximal graded exercise test eliciting RPE ≤ 15, thereby eliminating the need for maximal testing in obese women (Coquart, Lemaire, Dubart, Douillard, Luttenbacher, Wibaux and Garcin, 2009).

Hetzler, Seip, Boutcher, Pierce, Snead and Weltman (1991) examined the effect of exercise modality on RPEs at various lactate concentrations. Twenty-nine untrained males completed maximal treadmill and cycle ergometer tests that assessed lactate threshold, fixed blood lactate concentrations, HR, maximal oxygen uptake and RPEs. The treadmill protocol was a continuous, graded walk-run test of 3-minute stages. The initial velocity was 90 m/min, with a 10 m/min increase in each subsequent stage. Stages for the cycle ergometer test were also three minutes in duration, beginning at 60 rpm with no resistance. Subsequent stages increased power output by 14.7 W. Lactate samples were collected at rest and at the end of each 3-minute exercise stage. Rating of perceived exertion values for peripheral, respiratory-metabolic and overall were obtained during the final 15 seconds of each stage. Heart rate, VO2 and RPE were determined at power outputs corresponding to lactate threshold and fixed blood lactate concentrations. While significant differences between the treadmill and cycle ergometer modalities were found for HR and VO2 at lactate threshold, fixed blood lactate concentrations and maximal exercise, no significant differences were found in RPE. The study concluded that RPE at lactate threshold is unaffected by exercise modality involving the legs in untrained males, supporting the idea that perception of effort varies with changes in blood lactate. The authors also determined blood lactate may be an important physiological mediator of effort as measured by RPE.

Another study examined RPE and blood lactate concentration during sub-maximal running to determine if the relation observed between RPE, lactate threshold and blood lactate concentrations of an incremental protocol remained stable during a 30-minute, constant-velocity treadmill test. Nine healthy, recreationally active males initially completed a continuous, incremental, level running treadmill protocol to determine the VO2 and velocity associated with lactate threshold and blood lactate concentrations of 2.5 mM and 4.0 mM and at maximal concentration. The subjects then completed 3 running tests, each lasting 30 minutes, at the velocities associated with lactate threshold and blood lactate concentrations of 2.5 mM and 4.0 mM. Ratings of perceived exertion and blood samples were taken every 5 minutes, while HR and VO2 were continuously monitored. The study found RPEs associated with lactate threshold and blood lactate concentrations of 2.5 mM and 4.0 mM observed during the incremental protocol reflected RPEs associated with the blood lactate concentrations of the constant velocity running exercise of up to 30 minutes in duration. After the first 5-10 minutes of running, no significant differences were noted for RPE, VO2 and blood lactate concentrations when comparing the 30-minute protocol with the corresponding values at the same velocities during the incremental protocol. The study concluded RPE could be used to estimate blood lactate concentrations during running bouts of up to 30 minutes (Steed, Gaesser & Weltman, 1994).

Breslav, Epstein, Falk, Karni, Tenenbaum and Weinstein (1994) studied 93 young athletes during an incremental treadmill test to examine the relationship between RPE and ratings of perceived dyspnea (RPD). The subjects included physically active male college students and young male and female athletes who trained in gymnastics, table tennis, soccer and swimming. Each subject completed an incremental treadmill exercise that began at 9 km per hour and a 1.5% incline. The speed increased by 1 km per hour every minute until the subject reached a comfortably fast running pace. The incline increased by 2% every minute thereafter. The test was terminated when the subject reached exhaustion or could no longer maintain the pace. Oxygen consumption (VO2), respiratory exchange ratio (RER), minute ventilation (VE) and heart rate (HR) were recorded every 20 seconds. RPE and RPD were obtained during the last 15 seconds of each minute of the test. The relationships between RPE, RPD and the physiological variables were studied for the student group and each group of the different sports of the athletes. The results revealed a strong, positive correlation between RPE, RPD and the physiological variables ($p<0.001$). The highest correlation was observed between RPE and RPD ($r=0.995$), supporting the authors' hypothesis that a subject's evaluation of exertion is associated with breathing difficulties during aerobic exercise. As expected, a high correlation was seen between RPD and ventilation ($r=0.947$), between RPE and ventilation ($r=0.958$) and RPE and oxygen consumption ($r=0.902$). The study determined peak values of all variables were significantly higher in swimmers than in gymnasts, implying that aerobic athletes can reach a higher workload during incremental exercise, and therefore, obtain a higher RPE and RPD. The authors suggested that self-assessment of perceived intensity is partly influenced by the accompanying breathing difficulties and that aerobic athletes are able to determine RPE better than other athletes. They concluded RPD may replace RPE as a result of the strong relationship between self-assessment of workload and breathing difficulties.

The results of a meta-analysis by Chen et al. (2002) suggested that respiration rate is likely the best indicator of physical exertion of all physiological measures. Of four measures of oxygen uptake included in the meta-analysis, respiratory rate was found to serve as the more reliable and valid measure of physical exertion in both a research and clinical setting. All of the correlations for ratings of perceived exertion and respiration rate were greater than or equal to 0.70.

Since Borg developed his 15-point scale, many studies have related HR to perceived exertion. A study by Miller, Bell, Collis and Hoshizaki (1985) examined the relationship between RPE and HR in 105 female and 97 male post 50-year-old participants. They questioned if Borg's RPE scale provided an accurate measure for determining safe intensity levels during physical performance testing in an older population. Each participant completed one of two different walking activities. Approximately one half of the volunteers were instructed to walk 600 meters at a brisk, comfortable pace. The other half completed a 2-minute on-the-spot walk. This test required each participant to raise knees to a hip level while proceeding at a brisk, comfortable pace. RPE, HR, time for the 600-meter walk and number of steps for the 2-minute walk were recorded at the completion of each test. Mean RPEs and HRs for each test were correlated to determine their relationship. While the study found significant correlation between RPE and HR for females in both walking activities, a significant correlation was found for males in only the 2-minute on-the-spot walk. The study concluded that RPEs, along with HRs, may be used to measure exercise intensity in a variety of physical activities, and that a stronger relationship may exist between RPE and HR for women.

Gillach, Sallis, Buono, Patterson and Nader (1989) studied the relationship between HR, as a measure of physiological strain, and RPEs in 283 children (ages 10-14) and 295 adults. Their study questioned if children were as capable of expressing RPE as adults and if absolute levels of perceived exertion were predictive of physiological strain, as indicated by HR. Participants exercised on cycle ergometers at 50 rpm at an initial power of 25 watts. Power was increased 25 watts every 2 minutes. Heart rate and RPE were assessed at the end of each 2-minute stage. The authors cautioned that statistical methodology used in previous studies has often been inadequately described, causing an inflated correlation between HR and RPE. While their findings indicated children in this age group were as capable of expressing RPE as adults, they also concluded that RPE does not accurately reflect HR in either children or adults. The study did conclude that both children and adults are able to use RPE to discriminate changes in physiological strain, and thus properly monitor changes in exercise intensity.

Green et al. (2004) compared HRs and perceived exertion between treadmill and elliptical training. Their study of 13 male and 9 female participants chose an individualized protocol for maximal treadmill testing, with stages varying from 2-4 minutes. Participants reported an overall RPE, as well as RPE-legs and RPE-chest. Two elliptical tests on two separate days followed the treadmill test. In the first test, participants exercised until achieving a HR similar to their steady-state HR observed during the treadmill test. Ratings of perceived exertion were assessed for legs only, chest only and total body. In the second elliptical test, RPE from the treadmill test was produced. Results of this research indicated HRs were not significantly different between the treadmill and elliptical modes. Similarly, there were no significant differences for RPE-overall and RPE-chest between the treadmill and elliptical modes. The study did find elliptical exercise is perceived as more intense with respect to leg exertion. The findings showed RPE to be an effective tool for regulating HR during elliptical exercise.

The above studies examined physiological responses to exercise to determine their influence on perceived exertion. Lambrick et al. (2009), Faulkner et al. (2007) and Coquart et al. (2009) all concluded that RPE could be used as a reliable estimate of oxygen uptake. Similarly, Hetzler et al. (1991) and Steed et al. (1994) found RPE to be a reliable measure of blood lactate levels. Meta-analysis by Chen et al. (2002) found that respiratory rate is likely the best indicator of perceived exertion. Breslav et al. (1994) also determined there is a strong positive correlation between RPE and rate of perceived dyspnea. Studies related to heart rate resulted in conflicting findings. While HR and

RPE were found to be overall good measures of exercise intensity, Miller et al. (1985) determined that a stronger relationship may exist between HR and RPE for women than men. Although Gillach et al. (1989) concluded that RPE did not accurately reflect HR in either children or adults, Green et al. (2004) found RPE to be an accurate predictor of heart rate.

RPE Measurement Interval

A major challenge in the field of perceived exertion is that both physiological and psychological factors related to measurements of working capacity account for much of the variance (Borg, 1998). The field continues to be difficult to study because of the interaction of different physiological and psychological factors as previously reviewed. Such factors are at work during immensely varied actions, from performances with explosive strength exertion to long-term endurance exertion, or from intermittent to continuous exertion. Corbett et al. (2009) hypothesized that the perception of exertion may be influenced by the act of measurement itself. Their initial examination of ten moderately trained males determined a treadmill speed that elicited RPE of 10. This speed was maintained for 35 minutes during two subsequent tests that initially measured RPE at 5 minutes, and thereafter either at 10-minute intervals (RPE10) or 60-second intervals (RPE60 s). A counter-balanced, crossover design controlled the order of conditions. There were no significant differences in HR, VO2 or RER at each stage, but RPE60 s was higher than RPE10 at minutes 15, 25 and 35. Nine participants completed both exercise tests. One participant was unable to complete the 35-minute testing period in the RPE60 s condition due to volitional exhaustion, although he was able to complete the 35-minute testing period in the RPE10 condition. This study confirmed perception of exertion was influenced by the frequency of measurement during exercise at a fixed intensity. Their research also determined elevated RPE may have been induced by an increased associative attentional focus in the absence of any physiological changes. The researchers noted their findings should be interpreted with a degree of caution due to the relatively small sample size.

In a similar study, Han et al. (2001) found that more frequent inquiries of RPE led to higher RPEs at a given physiological intensity. Fifteen young men and women completed two maximal graded exercise tests using the standard Bruce treadmill protocol. During one test, RPE was measured at the end of each three-minute stage, and at the end of each minute during the other test. Participants were randomly assigned to one of the two treadmill protocols, with a crossover design for the other test within 48 hours. Heart rate, oxygen consumption, ventilation and respiratory exchange ratio did not differ during sub-maximal or peak exercise between the two tests. While peak RPEs did not differ between the two tests, RPEs were significantly higher ($p<0.01$) at each sub-maximal stage when RPE was measured at the end of each minute. The authors contended the heightened awareness of exercise-related physical signs/symptoms may have contributed to an increase in the subject's internal attentional focus, thereby contributing to a higher perception of exertion during the sub-maximal portions of the exercise test. The study recommended standardized RPE inquiry methods when collecting data for serial comparative or exercise prescriptive purposes. Again, the study tested a relatively small sample size.

Both studies concluded perceived exertion was influenced by the frequency of measurement interval despite the use of different participants, protocols, measurement intervals and test duration. The authors of both studies believed the changes in perceived exertion were the result of an increased internal attentional focus.

Few studies have investigated whether the perception of exertion may be influenced by attentional focus and existing research has studied a relatively small number of participants. Investigation of the relationship of HR, RPE and measurement interval should consider a protocol with a consistent increment in workload. The abrupt increase in workload of the Bruce protocol brings the participant to a maximal level in few stages. The modified Balke protocol provides a constant speed and a more gradual increase in workload to a sub-maximal target, but changes stages at two-minute intervals. A test protocol with more constant speed and a more gradual increase in workload that brings the participant to a sub-maximal target in three-minute stages can provide more uniform physiologic responses. Therefore, further studies are needed to determine if the frequency of measurement interval influences RPE during sub-maximal graded exercise testing on the treadmill.

CHAPTER III

METHODS

This study was designed to examine the effect of frequency of measurement interval on ratings of perceived exertion and heart rate during sub-maximal graded treadmill testing. It was hypothesized that the frequency of measurement interval would influence ratings of perceived exertion during sub-maximal treadmill testing, with no differences in heart rates observed during the same stages of testing.

Subjects

Thirteen female participants, ages 20-23 years, were recruited from the Eastern Illinois University student population to participate in this study (Appendix A). One participant was eliminated from the study following an episode of dizziness at the conclusion of her initial treadmill test. Each participant was assigned an identifying subject number to ensure confidentiality. All participants were non-athletes, had previous experience in the use of a treadmill and exercised aerobically at intensity levels similar to those attained in this study at least two to three times weekly. All participants provided written informed consent for participation conforming to procedures approved by the university's Institutional Review Board (Appendix B). All participants were screened for safety using the AHA/ACSM Health/Fitness Facility Pre-participation Screening Questionnaire prior to the study, found to be free of signs and symptoms of cardiovascular disease and considered to be apparently healthy (Appendix C). All were also informed of the risks associated with this study. Written instructions for the Borg 15-point scale were provided prior to day of testing so each participant would be familiar with the scale and able to choose the number that best described her level of exertion as the assessment progressed (Appendix D). Participants were further instructed that testing would take place on two nonconsecutive days at the same time of day (within two hours) in a controlled temperature environment. Additionally, all were asked to report for each testing session with very similar levels of hydration, food consumption and in similar clothing. Participants were not permitted to eat, smoke, or consume alcohol or caffeine for a minimum of two hours prior to testing. It was required that each participant be fever-free and free of antihistamines and/or cold medications for a minimum of four hours prior to testing. They were also instructed to refrain from additional aerobic or strength training exercise for a minimum of 24 hours prior to each assessment.

Procedures

Participants were alternately assigned to complete one of two graded treadmill tests with a crossover design for the other protocol on a nonconsecutive day. A Polar F6 heart rate monitor was utilized to measure resting HR prior to each test and exercise HRs throughout each test. The Borg 15-point RPE scale was in view throughout each assessment and participants were asked to give verbal RPEs. Participants were reminded level 6 of the Borg scale indicated no exertion at all and would not be an accurate rating of their exertion during the test. Prior to testing, participants were encouraged to ask questions concerning the Borg scale or to ask any other questions related to the test. During one treadmill test, RPE and HR were monitored once at the end of each three-minute test stage. During the other treadmill test, RPE and HR were monitored three times per stage, at the end of each minute. Participants were not permitted to know their HRs during the assessments. Each test began with a 2-minute warm-up period at 2.5 mph and 0% grade. The speed for each subsequent 3-minute stage was 3.5 mph. The grade at stage 1 was 0% and 5% at stage 2. Stages 3-6 increased at 2.5% per stage. Each participant was permitted to end the test when she had completed stage 6 at 3.5 mph and 15% grade, or her HR had reached 85% of age-predicted maximal heart rate (220 – age) or at any time she felt she was unable to continue the test. The speed and grade were gradually decreased during the cool-down period at the conclusion of each test. Each participant was permitted to leave the testing area when her HR had returned to within 20 beats of her resting HR.

Analysis

Means and standard deviations were calculated for HRs and RPEs at the end of each three-minute stage of the two test conditions. A 2-way multivariate analysis of variance (MANOVA) with repeated measures on both test stage and test condition was used to determine if there were significant differences in HR or RPE at each stage with more frequent inquiries. All analysis was conducted using SPSS 17.0 software with $p < .05$.

CHAPTER IV

RESULTS AND DISCUSSION

This study was designed to examine the effect of frequency of measurement interval on ratings of perceived exertion and heart rates during sub-maximal graded treadmill testing. It was hypothesized that the frequency of measurement interval would influence ratings of perceived exertion during sub-maximal treadmill testing, with no differences in heart rates observed during the same stages of testing.

Twelve recreationally trained female participants (21.83 ± 1.03 years of age) completed two sub-maximal graded treadmill tests. One test recorded HR and RPE every minute (HR-M, RPE-M), and a second test recorded HR and RPE at the end of each three-minute stage (HR-S, RPE-S). Six participants completed the HR-M, RPE-M test first, while the other six participants completed the HR-S, RPE-S test first. Sub-maximal comparisons were made from the data collected at the end of the first five stages of the tests, as these were the only stages completed by all participants.

Descriptive statistics using means and standard deviations were calculated for heart rates for the twelve participants. Results are presented in Table 1.

Table 1. Means and Standard Deviations for Heart Rate (bpm)

	HR-S	HR-M
Stage 1	109.7 ± 12.46	106.8 ± 10.20
Stage 2	130.3 ± 13.88	129.3 ± 12.66
Stage 3	145.6 ± 16.46	146.5 ± 13.64
Stage 4	162.1 ± 14.29	161.7 ± 11.63
Stage 5	172.8 ± 14.01	173.2 ± 11.31

HR-S = Heart rate recorded once at the end of each 3-minute stage

HR-M = Heart rate recorded three times per stage, at the end of each minute

Graphic representation of means and standard deviations for heart rates are illustrated in Figure 1.

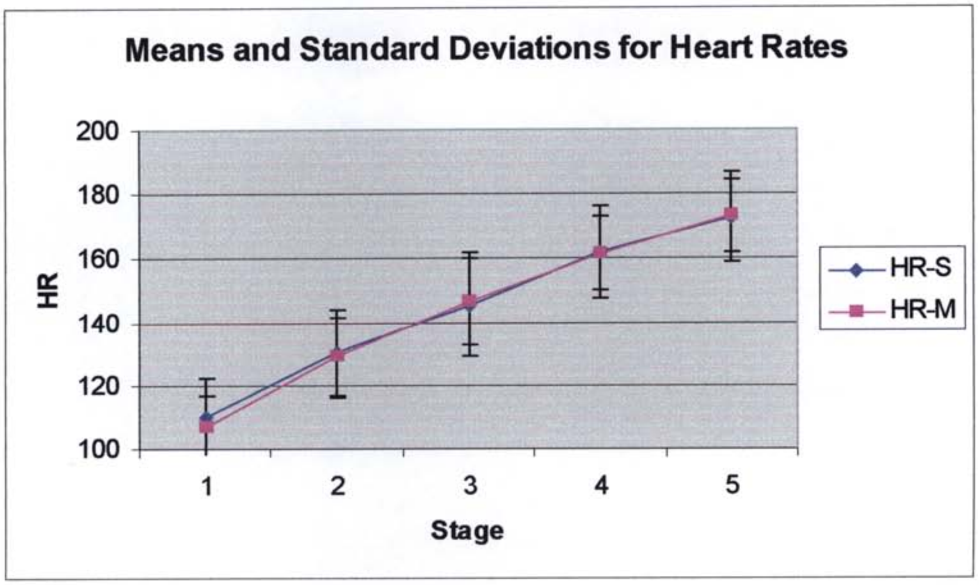

Figure 1. Heart rates were recorded during each stage for both trials. HR-S recorded heart rates once at the end of each three-minute stage. HR-M recorded heart rates three times per stage, at the end of each minute.

Descriptive statistics using means and standard deviations were calculated for ratings of perceived exertion for the twelve participants. Results are presented in Table 2.

Table 2. Means and Standard Deviations for Rating of Perceived Exertion

	RPE-S	**RPE-M**
Stage 1	8.8 ± 1.42	9.7 ± 1.56
Stage 2	10.8 ± 1.47	11.7 ± 1.78
Stage 3	12.8 ± 1.42	13.6 ± 1.88
Stage 4	14.6 ± 1.51	15.5 ± 2.11
Stage 5	16.8 ± 1.53	17.2 ± 1.99

RPE-S = Rating of perceived exertion reported once at the end of each three-minute stage

RPE-M = Rating of perceived exertion reported three times per stage, at the end of each minute

Graphic representation of means and standard deviations for ratings of perceived exertion are illustrated in Figure 2.

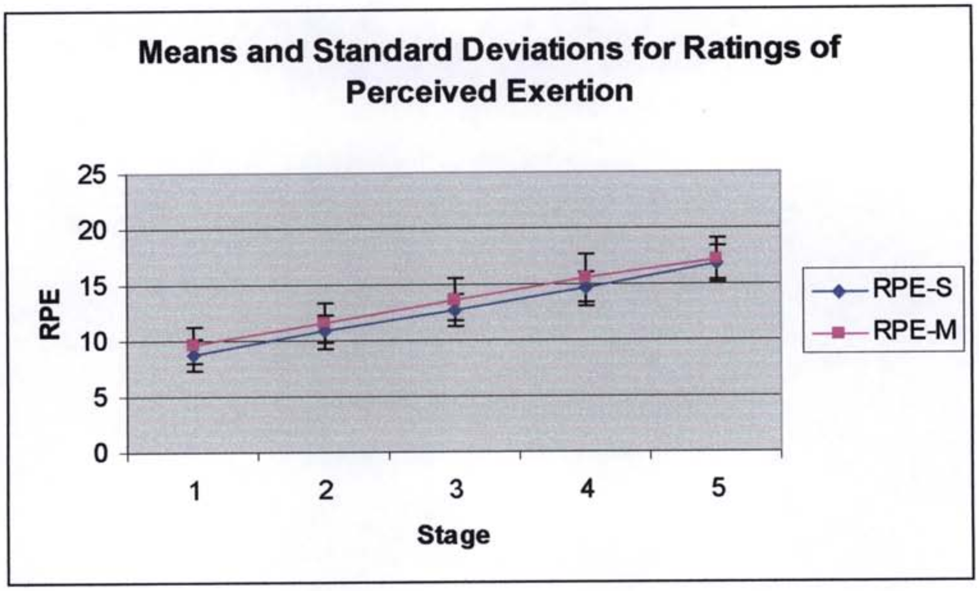

Figure 2. Ratings of perceived exertion were recorded during each stage for both trials. RPE-S recorded RPEs once at the end of each three-minute stage. RPE-M recorded RPEs three times per stage, at the end of each minute.

Results of Significance Testing

A 2-way MANOVA, with repeated measures on both test condition and test stage, was used to determine any significant differences in heart rate and rating of perceived exertion between the two test conditions. As expected, this analysis revealed significant increases in both heart rate and RPE as the workload increased. When comparing the two test conditions (assessing RPE at the end of each stage vs. assessing RPE each minute), the MANOVA revealed that there were no significant differences ($F=0.163$, $df=1$, $p=.694$) in heart rate at the end of each test stage. While the RPE at each test stage was slightly higher when the assessment was done more frequently (Figure 2), the MANOVA determined that these differences were not statistically significant ($F=2.384$, df-1, $p=.151$).

A MANOVA was also used to determine if test order might have been a factor influencing RPE. As shown in Table 3 and illustrated in Figure 3, subjects tended to give lower RPEs during their second test, regardless of the frequency of measurement. Analysis determined these differences approached statistical significance ($F=3.945$, $df=1$, $p=.072$).

Table 3. Means and Standard Deviations for Ratings of Perceived Exertion as Determined by Test Order

	First Test	**Second Test**
Stage 1	9.7 ± 1.50	8.8 ± 1.49
Stage 2	11.8 ± 1.53	10.7 ± 1.61
Stage 3	13.7 ± 1.61	12.7 ± 1.67
Stage 4	15.5 ± 1.88	14.6 ± 1.78
Stage 5	17.3 ± 1.72	16.7 ± 1.78

First Test = Rating of perceived exertion reported at the end of each stage in the first test for each participant

Second Test = Rating of perceived exertion reported at the end of each stage in the second test for each participant

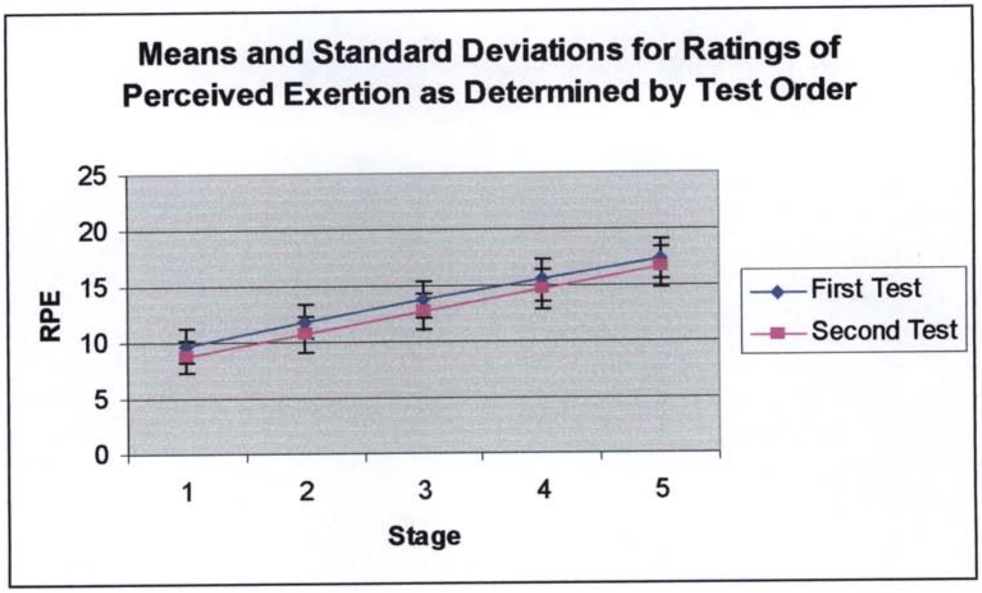

Figure 3. One half of the participants completed the RPE-S test first, followed by the RPE-M test, while the other half completed the RPE-M test first, followed by the RPE-S test. First Test represents RPEs reported during the first test for each participant. Second Test represents RPEs reported during the second test for each participant.

Discussion of Results

While previous research concluded that frequency of measurement interval influenced RPE during both sub-maximal, constant speed testing and maximal graded exercise testing, the results of this study did not confirm that the frequency of RPE inquiry significantly influenced the perceptual response at sub-maximal intensities. These findings were observed in the presence of matched exercise conditions. Each participant was tested at the same time of day (within two hours), in a controlled temperature environment with similar levels of hydration, post-prandial status and clothing. No eating, smoking or consumption of alcohol or caffeine was permitted for a minimum of two hours prior to testing. Each participant reported for testing fever-free and free of antihistamines or cold medications for a minimum of four hours prior to testing and each refrained from aerobic or strength training exercise for a minimum of 24 hours prior to each assessment.

While the mean RPE in this study was higher in all stages when reported at the end of each minute, it lacked the statistical significance reported by Corbett et al. (2009), who determined perception of exertion was influenced by frequency of measurement interval during sub-maximal treadmill testing at a fixed intensity. Their study of nine males chose a treadmill speed to elicit an RPE of 10 for each participant, with RPEs reported at 5, 15, 25 and 35 minutes in one trial and RPEs reported each minute in the other trial. Their results found higher RPEs when reported each minute, even though there were no significant differences between conditions in HR. Likewise, Han et al. (2001) found that more frequent inquiry of RPE led to higher values at a given physiological intensity in two maximal graded exercise tests. Their study exercised 15 young men and women to maximal levels. As with the present study, the authors chose three-minute stages, with RPEs recorded at the end of each stage in one trial and at the end of each minute in the other trial. While their study also found no physiological differences during sub-maximal or maximal exercise between the tests, RPEs were significantly higher at each sub-maximal stage when perceived exertion was assessed each minute. Both Corbett et al. and Han et al. contended that heightened awareness of physiological changes during the more frequent inquiry intervals might have increased a participant's internal attentional focus, which subsequently contributed to a higher perceived exertion. Similar heightened awareness was present in the current study. It is possible the more frequent inquiry sent a psychological signal to the participant that RPEs should increase to satisfy the expectations of the technician. However, the results of the current study did not support the findings of the previous studies that heightened awareness of physiological changes and expectations of the technician result in significantly higher perceived exertion. It is possible this difference in results could be explained by gender. Corbett et al. (2009) studied only males, while Han et al. (2001) studied males and females, but analyzed the subjects as one group. Milhevic (1978) concluded that psychological variables brought about different influence on perceived exertion for males and females. Other possible explanations for the difference in results of the current study are the differing test protocols and varying intervals of RPE inquiry. Corbett et al. (2009) also chose a sub-maximal protocol, but their subjects exercised at a constant speed for 35 minutes and the RPE inquiry interval varied from one minute to as much as ten minutes. Han et al. (2001) chose the maximal Bruce protocol, which has larger increments of workload. While their measurement interval matched the present study, only three stages were completed by all 15 subjects. In contrast, all subjects were able to complete five stages in this study with the less abrupt changes in workload.

Although this study did not determine that increased frequency of measurement interval resulted in significantly higher levels of perceived exertion, examination of each participant revealed noteworthy responses to RPE inquiry. RPEs and HRs for each participant are listed in Appendix E. Participant #4 reported RPE levels of 20 in her fifth and final stage of each trial, even though her HR was 13 bpm lower in the RPE-S trial than in her RPE-M trial. When HRs and RPEs were assessed each minute, participant #5 communicated RPE levels from 1-3 points higher at each stage than reported during the RPE-S trial, even though her HR was 7-14 bpm lower during each stage of her HR-M trial. Participant #6 reported RPE levels 3 points higher during the first two stages and 2 points higher in the third stage when assessed each minute, despite the fact that her HR varied only by as much as 3 bpm and was actually lower in the second and third stages when assessed each minute. When participant #7 stated her RPE levels were 1-2 points higher at each stage when assessed each minute, her HR actually was 3-13 bpm higher at each stage in that trial. Participant #8 communicated RPE levels from 3-4 points higher at each stage when recorded each minute. Her HRs were higher at each stage, but the mean increase was only 7 bpm. Despite a slight increase in HRs, participant #9 reported RPE levels from 1-3 points lower during each stage when assessed each minute. RPE values for participant #10 were 1-4 points higher at each stage when recorded each minute. Her HRs were also higher when assessed each minute, but only by as much as 6 bpm. The final participant reported RPE levels from 1-4 points higher when recorded each minute, despite the fact that her HRs were from 3-7 bpm lower when recorded only once per stage.

Further examination of test order suggested familiarization may have influenced RPE assessment in this study, with lower RPEs reported during the second test for each participant, regardless of the measurement interval. While comparing frequency of measurement interval, six participants (#5, 6, 7, 8, 10 and 12) reported significantly higher RPEs when questioned every minute and four participants (#1, 3, 9 and 11) reported higher RPEs when questioned at the end of the third minute. Mean RPE values for participants #2 and #4 were not significantly different between trials. When comparing test order, eight participants (#1, 3, 6, 8, 9, 10, 11 and 12) reported significantly higher RPE values on their first test, while only 2 participants (#5 and #7) reported higher RPE values on their second test. There was no significant difference for participants #2 and #4.

While participants in this present study were given written instructions concerning test protocol and the Borg scale prior to the day of the first test and were also encouraged to ask questions, Corbett et al. (2009) conducted a separate session prior to the day of testing to familiarize the subjects with their standardized instructions and the Borg scale. Han et al. (2001) read the standardized instructions for use of the Borg RPE scale to each subject immediately before each test.

It was also noted two participants questioned if even numbers were ever given in response to RPE inquiry, as only the odd numbers are given verbal anchors for the Borg 6-20 scale.

Conclusion

While there was a trend toward slightly higher RPE when participants reported their perceived exertion at the end of each minute (three times per stage) rather than once at the end of each three-minute stage, the differences were not statistically significant. The results of this study were contrary to the findings of Corbett et al. (2009) and Han et al. (2001), who confirmed that frequency of measurement interval did significantly influence perceptual responses at both sub-maximal and maximal intensities. Further analysis of test order revealed lower RPEs, approaching statistical significance, were given during the second test, regardless of the measurement interval.

CHAPTER V

SUMMARY AND CONCLUSION

This study examined the effect of frequency of measurement interval on rating of perceived exertion and heart rate during sub-maximal graded treadmill testing. It was hypothesized frequency of measurement interval would influence ratings of perceived exertion during sub-maximal treadmill testing, with no differences in heart rates observed during the same stages of testing. Twelve recreationally trained females (21.83 ± 1.03 years of age) completed two sub-maximal graded treadmill tests. One trial recorded HR and RPE once at the end of each three-minute stage, while the other trial recorded HR and RPE three times per stage at the end of each minute.

Summary of Findings

The study examined heart rate and perceived exertion in an effort to determine if increased frequency of measurement interval influenced ratings of perceived exertion during sub-maximal treadmill testing. Mean RPE was somewhat higher when participants reported perceived exertion at the end of each minute (three times per stage) rather than once at the end of each three-minute stage, but this increase in perceived exertion did not reach a level of statistical significance. The results did not confirm frequency of measurement interval influenced ratings of perceived exertion during sub-maximal treadmill testing. An incidental finding of this study determined lower RPEs were given during the second test, regardless of the frequency of measurement interval, suggesting test order influenced the results of this research.

Limitations/Recommendations

The findings of this study were obtained with a relatively small sample size of female participants, ranging in age from 20-23. Further testing in this field could benefit from a larger sample size of both genders with a greater range of ages. Increased familiarization with test protocol could reduce anxiety and the effect of test order. Instructions for the test and the Borg scale could be thoroughly explained and the protocol could be demonstrated in the testing area during an additional session prior to the first test. Continued research may have significant implications for studies requiring frequent measurement of perceived exertion.

Conclusion

It was hypothesized that the frequency of measurement interval influences ratings of perceived exertion during sub-maximal treadmill testing, with no differences in heart rates observed during the same stages of testing. The findings in this study of twelve recreationally trained females did not support this hypothesis or the findings of previous studies that determined perception of exertion was influenced by frequency of measurement interval at both maximal and sub-maximal intensities. Furthermore, the results of this study did not support the belief in previous studies that heightened awareness of physiological changes and conforming to expectations of the technician result in significantly higher perceived exertion.

WORKS CITED

Adams, S., Schafer, F., Tipton, K., & Johnson, K. (2008). Relationship between heart rate and rating of perceived exertion (RPE) during treadmill exercise in college women. *Missouri Journal of Health, Physical Education, Recreation & Dance, 18,* 119-120.

Baden, D., McLean, T., Tucker, R., Noakes, T., & St Clair Gibson, A. (2005). Effect of anticipation during unknown or unexpected exercise duration on rating of perceived exertion, affect, and physiological function. *British Journal of Sports Medicine, 39*(10), 742-746.

Baden, D., Warwick-Evans, L., & Lakomy, J. (2004). Am I nearly there? The effect of anticipated running distance on perceived exertion and attentional focus. *Journal of Sport & Exercise Psychology, 26*(2), 215-231.

Borg, G. (1982). Psychophysical bases of perceived exertion. *Medicine & Science in Sports & Exercise, 14*(5), 377-381.

Borg, G. (1985). An introduction to Borg's RPE-scale. Retrieved May 19, 2010, from Measuring Practice Effort, Website: http://coachsci.sdsu.edu/csa/vol15/borg.htm

Borg, G. (1998). *Borg's perceived exertion and pain scales.* Champaign, IL: Human Kinetics.

Breslav, I., Epstein, S., Falk, B., Karni, Y., Tenenbaum, G., & Weinstein, Y. (1994). Self-rating of perceived exertion and dyspnea by young athletes. *Biology of Sport, 11*(2), 91-99.

Chen, M., Fan, X., & Moe, S. (2002). Criterion-related validity of the Borg ratings of perceived exertion scale in healthy individuals: a meta-analysis. *Journal of Sports Sciences 20*(11), 873-900.

Coquart, J., Lemaire, C., Dubart, A., Douillard, C., Luttenbacher, D., Wibaux, F., & Garcin, M. (2009). Prediction of peak oxygen uptake from sub-maximal ratings of perceived exertion elicited during a graded exercise test in obese women. *Psychophysiology, 46*(6), 1150-1153.

Corbett, J., Vance, S., Lomax, M., & Barwood, M. (2009). Measurement frequency influences the rating of perceived exertion during sub-maximal treadmill running. *European Journal of Applied Physiology, 106*(2), 311-313.

Dishman, R.K., Graham, R.E., Holly, R.G., & Tieman, J.G. (1991). Estimates of type A behavior do not predict perceived exertion during graded exercise. *Medicine and Science in Sports and Exercise, 23*(11), 1276-1282.

Doherty, M., Smith, P., Hughes, M., & Collins, D. (2001). Rating of perceived exertion during high-intensity treadmill running. *Medicine & Science in Sports & Exercise, 33*(11), 1953-1958.

Faulkner, J., Parfitt, G., & Eston, R. (2007). Prediction of maximal oxygen uptake from ratings of perceived exertion and heart rate during a perceptually-regulated sub-maximal exercise test in active and sedentary participants. *European Journal of Applied Psychology, 101*(3), 397- 407.

Gillach, M., Sallis, J., Buono, M., Patterson, P., & Nader, P. (1989). The relationship between perceived exertion and heart rate in children and adults. *Pediatric Exercise Science, 1*(4), 360-368.

Glass, S., Whaley, M., & Wegner, M. (1991). Ratings of perceived exertion among standard treadmill protocols and steady state running. *International Journal of Sports Medicine, 12*(1), 77-82.

Green, J., Crews, T., Pritchett, R., Mathfield, C., & Hall, L. (2004). Heart rate and ratings of perceived exertion during treadmill and elliptical exercise training. *Perceptual & Motor Skills, 98*(1), 340-348.

Hampson, D., Gibson, A., Lambert, M., Dugas, J., Lambert, E., & Noakes, T. (2004). Deception and perceived exertion during high-intensity running bouts. *Perceptual and Motor Skills, 98*(3), 1027-1038.

Hampson, D., Gibson, A., Lambert, M., & Noakes, T. (2001). The influence of sensory cues on the perception of exertion during exercise and central regulation of exercise performance. *Sports Medicine, 31*(13), 935-952.

Han, S., Whaley, M., & Kaminsky, L. (2001). Influence of inquiry frequency on ratings of perceived exertion during graded exercise testing. *International Journal of Applied Sports Sciences, 13*(2), 1-11.

Hetzler, R.K., Seip, R.L., Boutcher, S.H., Pierce, E., Snead, D., & Weltman, A. (1991). Effect of exercise modality on ratings of perceived exertion at various lactate concentrations. *Medicine & Science in Sports & Exercise, 12*(1), 88-92.

Lambrick, D., Faulkner, J., Rowlands, A., & Eston, R. (2009). Prediction of maximal oxygen uptake from submaximal ratings of perceived exertion and heart rate during a continuous exercise test: the efficacy of RPE 13. *European Journal of Applied Physiology, 107*(1), 1-9.

Mahon, A.D., Plank, D.M., & Hipp, M.J. (2003). The influence of exercise test protocol on perceived exertion at submaximal exercise intensities in children. *Canadian Journal of Applied Physiology, 28*(1), 53-63.

Milhevic, P.M. (1978). Psychological influences on perceived exertion [Abstract]. *Medicine and Science in Sports, 10*(1), 52.

Miller, G.D., Bell, R.D., Collis, M.L., & Hoshizaki, T.B. (1985). The relationship between perceived exertion and heart rate of post 50 year-old volunteers in two different walking activities. *Journal of Human Movement Studies, 11*(4), 187-195.

Noble, B. J., & Robertson, R. J. (1996). *Perceived exertion.* Champaign, IL: Human Kinetics.

Pender, N. J., Bar-Or, O., Wilk, B., & Mitchell, S. (2002). Self-efficacy and perceived exertion of girls during exercise. *Nursing Research, 51*(2), 86-91.

Rejeski, W.J., & Ribisl, P.M. (1980). Expected task duration and perceived effort: an attributional analysis. *Journal of Sport Psychology, 2*(3), 227-236.

Skinner, J.S., Hutsler, R., Bergsteinova, V., & Buskirk, E.R. (1973). The validity and reliability of a rating scale of perceived exertion. *Medicine and Science in Sports, 5*(2), 94-96.

Stanley, C., Pargman, D., & Tenenbaum, G. (2007). The effect of attentional coping strategies on perceived exertion in a cycling task. *Journal of Applied Sport Psychology, 19*(3), 352-363.

Steed, J., Gaesser, G.A., & Weltman, A. (1994). Rating of perceived exertion and blood lactate concentration during submaximal running. *Medicine and Science in Sports and Exercise, 26*(6), 797-803.

Williams, J.G., & Eston, R.G. (1986). Does personality influence the perception of effort? the results from a study of secondary schoolboys. *Physical Education Review 9*(2), 94-99.

Yamaji, K., Yokota, Y., & Shephard, R. (1992). A comparison of the perceived and the ECG measured heart rate during cycle ergometer, treadmill and stairmill exercise before and after perceived heart rate training. *Journal of Sports Medicine & Physical Fitness, 32*(3), 271-281.

APPENDIX A

Master's Thesis Study

- Participants are needed for a research study to examine the relationship between heart rate and rating of perceived exertion (RPE) during treadmill walking.
- Participants need to be female EIU students (non-athletes) who exercise aerobically at least 2-3 times per week. Previous experience in use of a treadmill is required.
- Two testing sessions will take place on two non-consecutive days in the Human Performance Lab at 1011 Lantz. Each will be completed in less than one hour.

East test gradually progresses to a maximal speed of 3.5 mph (a brisk walking speed) and 15% incline. Heart rate will be monitored throughout the test until it has increased to about 170 bpm or until you have walked for 20 minutes. Each test may be ended at any time you feel you are unable to continue. You will be asked to verbally give your rating of perceived exertion during each stage of the test.

If you are interested or would like more information, please contact:

Sue Stout
EIU graduate student
Department of Kinesiology and Sports Studies
217-268-3190
slstout@eiu.edu

APPENDIX B

CONSENT TO PARTICIPATE IN RESEARCH

Rating of Perceived Exertion During Sub-Maximal Treadmill Walking

You are invited to participate in a research study conducted by Sue Stout, graduate student, and Dr. Phyllis Croisant, from the Department of Kinesiology and Sports Studies at Eastern Illinois University. Your participation in this study is entirely voluntary. Please ask questions about anything you do not understand, before deciding whether or not to participate.

- ### PURPOSE OF THE STUDY

The purpose of this study is to test the relationship between heart rate and rating of perceived exertion during exercise.

- ### PROCEDURES

If you volunteer to participate in this study, you will be asked to:

Complete the AHA/ACSM Health/Fitness Facility Pre-participation Screening Questionnaire to ensure you are free of signs and symptoms of cardiovascular disease and considered to be apparently healthy.

Read and understand the Instructions for Borg Rating of Perceived Exertion Scale in order to be able to choose the number that best describes your level of exertion as the assessment progresses.

The questionnaire and reading of instructions will take approximately 10 minutes.

This study requires that you are not pregnant, are not an athlete, but exercise aerobically at least 2-3 times per week and have previous experience in use of a treadmill. Your testing will take place on two nonconsecutive days at the same time of day (within 2 hours) in a controlled temperature environment. You will be asked to report for each assessment with very similar levels of hydration, food consumption and in similar clothing. You will not be able to eat, smoke, or consume alcohol or caffeine for a minimum of 2 hours prior to testing. You must be fever-free and free of antihistamines or cold medications for a minimum of 4 hours prior to testing. You will not be able to participate in aerobic or strength training exercise for a minimum of 24 hours prior to each assessment.

Your resting heart rate will be measured before the test begins. Your heart rate will be monitored with a Polar heart rate monitor on a strap worn around your ribcage throughout the test. You will be asked to verbally give your rating of perceived exertion during each stage of the test.

Each test will begin with a 2-minute warm-up period at 2.5 mph (an easy walking speed) and 0% incline that will allow you to become familiar with the treadmill. The speed will then be increased to 3.5 mph (a brisk walking speed) for the rest of the test. The incline of the treadmill will increase every few minutes until your heart rate has increased to about 170 bpm or until you have walked for 20 minutes. You may also end the test at any time you feel you are unable to continue. At the conclusion of the test, the speed and incline will be gradually decreased during the cool-down period.

You will be permitted to leave the testing area when your heart rate has returned to within 20 beats of your resting heart rate. The anticipated time for this testing period, including questionnaire, instructions, warm-up, cool-down and final monitoring of heart rate is less than one hour.

- **POTENTIAL RISKS AND DISCOMFORTS**

While this treadmill walking test is no more intense than your regular workout, there is a risk that during the test, you may feel tired, light headed, or experience shortness of breath causing you to trip, faint or fall. This risk of falling will be minimized with treadmill handrails and the careful assistance and spotting of the researcher. Testing will be done individually, so there will always be a 1:1 ratio of participant and researcher. You will be able to terminate the test at any time you feel you are unable to continue.

Eastern Illinois University is unable to offer financial compensation or absorb the costs of treatment should you be injured as a result of participating in this study.

- **POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY**

This study will have no direct benefit to you as a participant.

This research will benefit society by studying the relationship between heart rate and rating of perceived exertion.

- **CONFIDENTIALITY**

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. Confidentiality will be maintained by means of securing your file in a locked cabinet in my home, and by coding all data files that are used for statistical analysis with a subject number rather than with your name. The only persons authorized to access your file will be Sue Stout, researcher, and thesis advisor Dr. Phyllis Croisant. The file will be stored in a locked cabinet for three years and then destroyed by shredding.

Reports written about this study will not contain any information about individuals or any information from which you can be identified as a participant. The reports will not contain your name.

- **PARTICIPATION AND WITHDRAWAL**

Participation in this research study is voluntary and not a requirement or a condition for being the recipient of benefits or services from Eastern Illinois University or any other organization sponsoring the research project. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind or loss of benefits or services to which you are otherwise entitled. There is no penalty if you withdraw from the study and you will not lose any benefits to which you are otherwise entitled.

- **IDENTIFICATION OF INVESTIGATORS**

If you have any questions or concerns about this research, please contact:

Sue Stout
slstout@eiu.edu
217-268-3190

Phyllis T. Croisant, Ph.D.
ptcroisant@eiu.edu
Office: 217-581-7596

- **RIGHTS OF RESEARCH SUBJECTS**

If you have any questions or concerns about the treatment of human participants in this study, you may call or write:

Institutional Review Board
Eastern Illinois University
600 Lincoln Ave.
Charleston, IL 61920
Telephone: (217) 581-8576
E-mail: eiuirb@www.eiu.edu

You will be given the opportunity to discuss any questions about your rights as a research subject with a member of the IRB. The IRB is an independent committee composed of members of the University community, as well as lay members of the community not connected with EIU. The IRB has reviewed and approved this study.

I voluntarily agree to participate in this study. I understand that I am free to withdraw my consent and discontinue my participation at any time. I have been given a copy of this form.

Printed Name of Participant

Signature of Participant Date

I, the undersigned, have defined and fully explained the investigation to the above subject.

Signature of Investigator Date

APPENDIX C

AHA/ACSM Health/Fitness Facility Pre-participation Screening Questionnaire*
Assess your health status by marking all *true* statements

History
You have had:
___ a heart attack
___ heart surgery
___ cardiac catheterization
___ coronary angioplasty (PTCA)
___ pacemaker / implantable cardiac
___ defibrillator / rhythm disturbance
___ heart valve disease
___ heart failure
___ heart transplantation
___ congenital heart disease

If you marked any of these statements in this section, consult your physician or other appropriate health care provider before engaging in exercise. You may need to use a facility with a medically qualified staff.

Symptoms
___ You experience chest discomfort with exertion
___ You experience unreasonable breathlessness
___ You experience dizziness, fainting, or blackouts
___ You take heart medications

Other health issues
___ You have diabetes
___ You have asthma or other lung disease
___ You have burning or cramping sensation in your lower legs when walking short distances
___ You have musculoskeletal problems that limit your physical activity
___ You have concerns about the safety of exercise
___ You take prescription medication(s)
___ You are pregnant

Cardiovascular risk factors
___ You are a man older than 45 years
___ You are a woman older than 55 years, have had a hysterectomy, or a postmenopausal
___ You smoke, or quit smoking within the last 6 months
___ Your blood pressure is greater than 140/90 mm Hg
___ You do not know your blood pressure
___ You take blood pressure medication
___ Your blood cholesterol level is greater than 200 mg/dL
___ You do not know your cholesterol level
___ You have a close blood relative who had a heart attack or heart surgery before ages 55 (father or brother) or age 65 (mother or sister)
___ You are physically inactive (i.e., you get less than 30 minutes of physical activity on at least 3 days per week)
___ You are greater than 20 pounds overweight

If you marked two or more of the statements in this section you should consult your physician or other appropriate health care provider before engaging in exercise. You might benefit from using a facility with a **professionally qualified exercise staff** to guide your exercise program.

___ none of the above

You should be able to exercise safely without consulting your physician or other appropriate health care provider in a self-guided program or almost any facility that meets your exercise program needs.

* modified from American College of Sports Medicine and American Heart Association, ACSM/AHA Joint Position Statement: Recommendations for cardiovascular screening, staffing, and emergency policies at health/fitness facilities. Med Sci Sports Exerc 1998: 1018.

Professionally qualified exercise staff refers to appropriately trained individuals who possess academic training, practical and clinical knowledge, skills, and abilities.

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APPENDIX D

Instructions for Borg Rating of Perceived Exertion (RPE) Scale

While doing physical activity, we want you to rate your perception of exertion. This feeling should reflect how heavy and strenuous the exercise feels to you, combining all sensations and feelings of physical stress, effort, and fatigue. Do not concern yourself with any one factor such as leg pain or shortness of breath, but try to focus on your total feeling of exertion.

Look at the rating scale below while you are engaging in an activity; it ranges from 6 to 20, where 6 means "no exertion at all" and 20 means "maximal exertion." Choose the number from below that best describes your level of exertion. This will give you a good idea of the intensity level of your activity, and you can use this information to speed up or slow down your movements to reach your desired range.

Try to appraise your feeling of exertion as honestly as possible, without thinking about what the actual physical load is. Your own feeling of effort and exertion is important, not how it compares to other people's. Look at the scales and the expressions and then give a number.

6 No exertion at all

7

Extremely light (7.5)

8

9 Very light

10

11 Light

12

13 Somewhat hard

14

15 Hard (heavy)

16

17 Very hard

18

19 Extremely hard

20 Maximal exertion

9 corresponds to "very light" exercise. For a healthy person, it is like walking slowly at his or her own pace for some minutes

13 on the scale is "somewhat hard" exercise, but it still feels OK to continue.

17 "very hard" is very strenuous. A healthy person can still go on, but he or she really has to push him- or herself. It feels very heavy, and the person is very tired.

19 on the scale is an extremely strenuous exercise level. For most people this is the most strenuous exercise they have ever experienced.

Borg RPE scale

© Gunnar Borg, 1970, 1985, 1994, 1998

APPENDIX E

Raw Data

Ratings of Perceived Exertion reported by each participant at the end of each three-minute stage: S = RPE reported once at the end of the stage. M = RPE reported three times per stage at the end of each minute.

Participant	Stage 1		Stage 2		Stage 3		Stage 4		Stage 5	
	S	M	S	M	S	M	S	M	S	M
1	12	11	13	12	14	14	16	15	17	17
2	9	8	12	11	13	13	14	14	18	18
3	10	9	13	12	15	14	15	15	17	16
4	8	9	11	11	15	15	18	19	20	20
5	10	11	11	13	13	15	14	17	16	18
6	7	10	9	12	11	13	13	14	15	15
7	9	11	10	12	12	13	14	15	15	16
8	8	12	10	14	12	15	14	17	16	19
9	9	8	12	9	13	11	15	13	17	15
10	8	11	11	14	13	17	16	18	19	20
11	7	7	9	8	11	10	13	12	16	14
12	8	9	9	12	11	13	13	17	16	18

Heart Rates recorded for each participant at the end of each three-minute stage: S = HR recorded once at the end of the stage. M = HR recorded three times per stage at the end of each minute.

Participant	Stage 1		Stage 2		Stage 3		Stage 4		Stage 5	
	S	M	S	M	S	M	S	M	S	M
1	126	94	122	118	121	141	156	148	170	165
2	119	124	147	148	165	162	178	173	187	186
3	101	110	141	137	148	153	171	169	180	175
4	121	105	139	127	150	143	150	155	148	161
5	124	117	144	132	160	146	176	163	180	173
6	93	96	112	111	124	121	143	145	159	156
7	101	104	120	133	138	147	154	161	163	166
8	95	100	116	120	132	140	149	155	159	172
9	93	94	108	112	127	127	142	147	164	163
10	119	122	145	151	165	169	177	179	185	187
11	112	107	135	131	158	157	174	173	188	187
12	112	108	134	131	159	152	175	172	190	187